Performance Analysis of Patch-HIS Arrays for Visually Impaired Aid System

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Abstract: A High Impedance Surface (HIS) metasurface has been designed to be combine with patch-based antennas to improve their radiation properties for the Electronic Travel Aid (ETA) application for which they are intended. A wearable patch and patch-HIS arrays antennas have been designed *ad hoc,* in the 24.05-24.25GHz frequency band. In order to evaluate the performance of the antennas, electromagnetic images have been obtained and a metric have been applied to compare their quality and evaluate their behavior for the application.

The traditional travel aids used by visually impaired people have been the white cane and the guide dog. However, these solutions are not enough for autonomous mobility. In this context, it seems that millimeter wave radars may be appropriate for obstacle detection, due to its great development in recent years and the relatively high frequency in which this technology operates, which allows obtaining compact radar modules. In order to improve the performance of the antennas (e.g., front-to-back ratio, gain, etc.), antennas surrounded by HIS unit cells have been proposed [1]. In this work, the effects of these nonideal radiators are analyzed for a short distance avoidance collision application. Electromagnetic images will be obtained by a flexible sum-and-delay algorithm:

$$\rho(\vec{r}) = \sum_{m=1}^{M} \sum_{n=1}^{N} S_r(m,n) \cdot e^{jk_m 2|\vec{r}-\vec{r_n}|} \tag{1}$$

Sr refers to the acquired data, *M* stands for the number of frequencies while *N* indicates the acquisition points. *km* represents the wavenumber at the m-frequency, $\vec{r}$ indicates the pixel where the reflectivity is going to be calculated and $\vec{r_n}$ refers to the n-measured position. This algorithm assumes that a perfect spherical wavefront is employed for calculating the reflectivity. However, if the waves are not created from the same position, dispersive behavior along frequency is expected, producing unwanted artifacts in images.

The performance of patch-based antennas, all of them designed in RO3003, have been analyzed for this application. A simple patch antenna (*Patch*), a two-element patch array with a wall of HIS unit cells between its elements to reduce the coupling (*Array-HIS Wall*) and including a row of unit cells surrounding the patches to reduce the possible surface waves (*Array-HIS Row*) have been evaluated. The fabricated prototypes are shown in Figure 1a. TABLE 1 summarizes the radiation properties of each antenna for the center frequency of the operating bandwidth. More details about the antennas and metasurface design can be found in [1].

Electromagnetic images have been obtained from a monostatic set-up (see Figure 1b). A simple target has been employed, as this kind of objects provides a simple response, which facilitates the analysis of the results. In this work a metal strip of 4x340mm is used as the target. It is placed over the antenna at a distance of 13.2cm, so that far-field conditions are met. The synthetic aperture length is set in 30 cm in the direction of the x-axis (see Figure 1b) and the sampling step has been established in order to satisfy the Nyquist theorem (~λ/4 at 24.25GHz). The data have been acquired with a Vector Network Analyzer (VNA) simulating a step-frequency continuous wave (SCFW) radar. Figure 1c, d and e show the electromagnetic images obtained with each antenna, where the contour of the object has been highlighted in magenta. In order to quantitatively compare the quality of the images their entropy (IE) have been calculated according to [2], and the results are indicated in TABLE 1. The smaller the entropy value, the better quality of the image. It can be concluded that all the antennas detect the target (see Figure 1c, d and e). The *Array-HIS Row* design, which reduce the coupling between the array elements, improves the IE result with respect to the simple *Patch*. As it can be observed in Figure 1d, the spread energy around the target is lower than the other cases. However, surrounding the array by a row of unit cells does not improve the IE result obtained with the *Wall Array-HIS*, although it performs better than the *Patch*. Therefore, few unit cells in the middle of the array elements contribute to reduce the coupling between them, modifying the radiation diagram of the antenna, so that a better performance is reached for this application.

TABLE 1. Simulated and measured radiation properties of the antennas and TCR results.

	Simulated				Measured	IE
Antenna	G [dB]	D [dB]	η [%]	FTBR [dB]	G [dB]	
Patch	6.8	6.8	100	20.2	7.4	6.9
Array-HIS Wall	8	8	100	24.8	8.5	6.5
Array-HIS Row	7.9	7.9	100	36.7	7.9	6.8

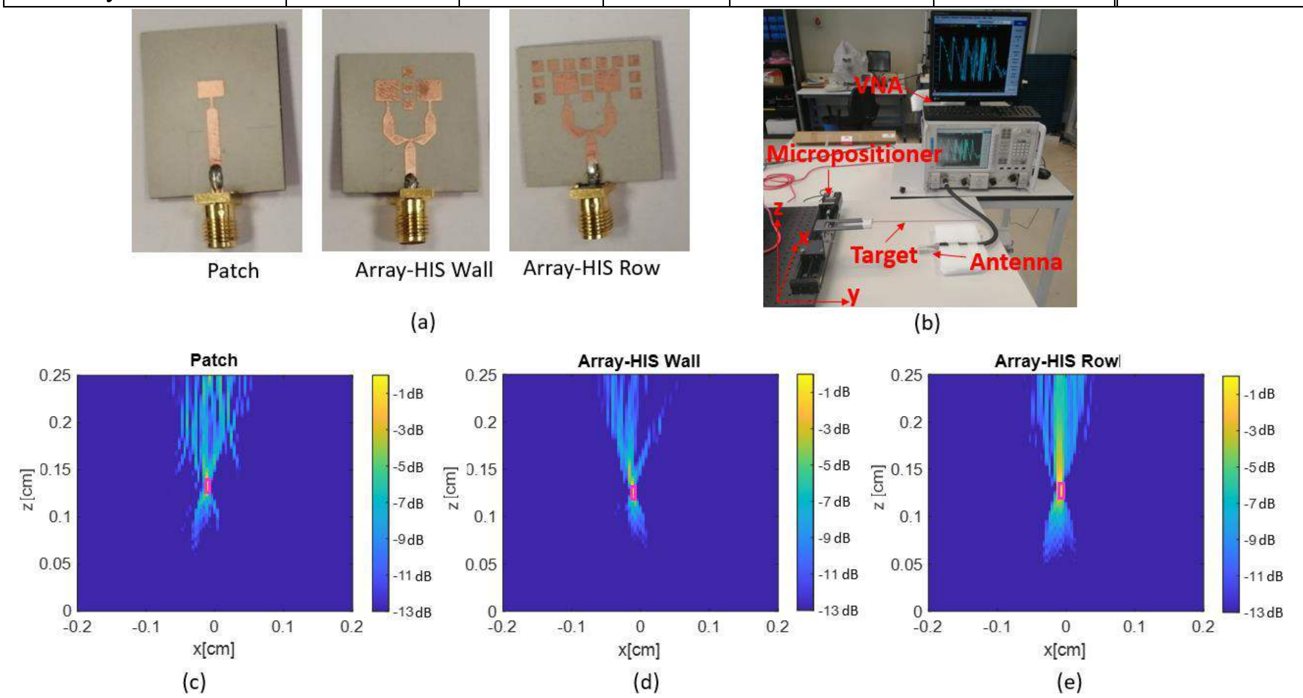

Figure 1. (a) Antennas under evaluation, (b) SAR measurement set-up, (c) Patch Electromagnetic Image, (c) Array-HIS Wall Electromagnetic Image, (e) Array-HIS Row Electromagnetic Image.

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References

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